INDOOR AIR QUALITY ASSESSMENT

Helen Mae Sauter Elementary School
130 Elm Street
Gardner, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
August 2006

Background/Introduction

At the request of John Fairbanks, Business Manager, Gardner Public Schools, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), provided assistance and consultation regarding indoor air quality at the Helen Mae Sauter Elementary School (HMSES), 130 Elm Street, Gardner, Massachusetts. Concerns regarding water damage and potential mold growth prompted the assessment. On February 17, 2006, Michael Feeney, Director of CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program visited the HMSES to conduct an assessment.

The school is a three-story yellow brick building constructed in 1899. The building contains general classrooms, a gymnasium, library, office space, an attic and an occupied basement. Windows in the building are openable.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Hnu, Model 102 Snap-on Photo Ionization Detector (PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The school houses grades 1-3 and has a student population of approximately 250 and a staff of approximately 20. Tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) parts of air in seven of twenty seven areas surveyed, indicating inadequate air exchange in some areas. Please note that some areas with carbon dioxide levels below 800 ppm were sparsely occupied, which can greatly reduce carbon dioxide. Carbon dioxide levels in these areas would be expected to rise with increased population.

Fresh air in classrooms is supplied by a unit ventilator (univent) system (Figure 1). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 1) and return air through an air intake located at the base of each unit. Fresh and return air are mixed, filtered, heated or cooled and provided to classrooms through an air diffuser located in the top of the unit. Univents have control settings of off, low or high. Adjustable louvers control the ratio of outside to recirculated air. Obstructions to airflow, such as items stored on or in front of univents were seen in some areas. In order for univents to provide fresh air as designed, units must be activated while rooms are occupied and air diffusers should remain free of obstructions.

Exhaust ventilation on the lower floor is provided by unit exhaust vents (UEVs) (Picture 2). This equipment contains two fans that draw air from the building, several of which were not operating during the assessment. Without functional mechanical fresh air supply or exhaust ventilation, environmental pollutants can accumulate within the building and lead to air quality/comfort complaints.

During summer months, air exchange is facilitated by the use of openable windows. The building was configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. Open hallway doors maintain a pathway for airflow. This design allows for airflow to enter an open window, pass through a room and an open door, enter the hallway, pass through the opposing room door, into that room and exit the building on the leeward side (opposite the windward side) (Figure 2). With all windows and hallway doors open, airflow can be maintained in a building regardless of the direction of the wind. This system fails if the windows or doors are closed (Figure 3). Most hallway doors in the building were open during the assessment.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air (20 for offices) or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints.

The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature measurements ranged from 68° F to 75° F, which were within the MDPH recommended comfort guidelines in all but one area surveyed. The MDPH recommends that indoor air temperatures be maintained in a range of 70 ° F to 78 ° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity ranged from 28 to 44 percent, which was within the MDPH recommended comfort range in most areas surveyed during the assessment. The MDPH recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. During the heating season, relative humidity levels would be expected to drop below the recommended comfort range. The sensation of dryness and irritation is common in a low relative humidity environment. For buildings in New England, periods of low relative humidity during the winter are often unavoidable.

Microbial/Moisture Concerns

Several areas had water-stained ceiling tiles, which can indicate leaks from the roof or plumbing system. Of note is the library and office suite of rooms containing the guidance and speech programs on the third floor (Picture 3), both of which had walls that are covered with acoustic tile that were water damaged. The water damage to the acoustic wall tiles appears to be related to a historic leak that originated in the attic above this area. CEH staff were in the HMSES during a two hour, wind-driven rainstorm [measured wind gust up to 60 MPH (Weather Underground, 2006)]. CEH staff examined the attic after this rainstorm and did not observe any active leaks. Water-damaged ceiling and acoustic wall tiles can provide a source for mold and should be replaced after a water leak is discovered and repaired. A number of areas around the basement exterior wall showed signs of water damage (Picture 4) or efflorescence (Picture 5). Efflorescence is caused by water penetration through brick, dissolving minerals within the brick as it flows through. The water evaporates leaving a dry white residue. While efflorescence is a characteristic sign of water penetration, it is not mold growth. The presence of efflorescence can indicate that water is penetrating through the exterior wall system.

Water damaged tiles in the basement may be related to pooling/splashing water at the base of the building. The roof edge does not appear to have a gutter/downspout system (Picture 6). Rainwater pours off the roof, which then impacts on the tarmac at the base of the building, allowing for the foundation wall, plugs in former windows frames (Picture 7) and window systems to become moistened during rain. Rainwater should be drained from the roof and be directed away from the building in order to prevent water penetration through the foundation.

The kitchen contains an unvented dish washing machine (Picture 8). During the course of use, a dishwashing machine of this type can be a significant source of water vapor (steam) that can enter the indoor environment. This equipment, if used, should have a mechanical exhaust vent to eject steam outdoors.

Other Concerns

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems

(ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a).

Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. Outdoor PM2.5 concentrations were measured at 10 $\mu g/m^3$ (Table 1). PM2.5 levels measured in the school were between 1 to 40 $\mu g/m^3$, which were below outdoor measurements and the NAAQS of 65 $\mu g/m^3$ (Table 1). Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. In an effort to identify materials that can potentially increase indoor TVOC concentrations, MDPH staff examined classrooms for products containing these respiratory irritants. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat. Cleaning products were also found on countertops in some classrooms. Like dry erase materials, cleaning products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals.

Several other conditions that can affect indoor air quality were noted during the assessment. In some classrooms items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Univents are outfitted with a filter that strains particulates from airflow. Filters were cut from filter media and installed in each univent (Picture 9). Spaces were observed between the filter medium and the cabinet wall, which can result in air bypassing filters. In addition, holes were found in the cabinet above the filters, which can allow for unfiltered air and particles to bypass the filter (Picture 10). In this condition dust, dirt and other debris can then be re-aerosolized by the ventilation system. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed.

The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the unit due to increased resistance (called pressure drop). Prior to any increase of filtration, each univent should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas TVOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

Conclusions/Recommendations

In view of the findings at the time of the assessment, the following recommendations are made:

1. Remove water damaged ceiling and acoustic wall tiles . This measure will remove actively growing mold colonies that may be present. Remove mold contaminated materials in a manner consistent with recommendations in "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency (US EPA, 2001). Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
2. Examine the feasibility of installing a gutter/downspout system for the roof to prevent excess water exposure to the exterior wall. Ensure that the downspout drains water at a point that is at least 5 feet away from the exterior wall of the building.

3. Take steps to prevent prolonged moisture contact with the foundation. These steps may include:

    a. Removing foliage, gardens and mulch to at least five feet away from the foundation.

    b. Improving the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek, & Brennan, 2001).

    c. Installing a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek, & Brennan, 2001).

4. Operate all ventilation systems throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy independent of thermostat control to maximize air exchange. To increase airflow in classrooms, set univent controls to "high".

5. Remove all blockages from univents to ensure adequate airflow.

6. Consider adopting a balancing schedule of every 5 years for mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).

7. Change filters for air-handling equipment as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces in between allowing bypass of unfiltered air into the unit.

8. Seal all holes in univent cabinets with an appropriate foil tape.

9. Use openable windows in conjunction with classroom univents and exhaust vents to increase air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.

10. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (e.g., throat and sinus irritations).
11. Examine the feasibility of installing a mechanical exhaust vent for the automatic dishwasher in the kitchen.
12. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
13. Consider discontinuing the use of tennis balls on walker legs to prevent latex dust generation. Alternative "glides" can commonly be purchased from office supply stores, see Picture 11 for an example.
14. Consider adopting the US EPA document, "Tools for Schools", to maintain a good indoor air quality environment on the building (US EPA, 2000b). This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.
15. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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Picture 1

Univent

Picture 2

Unit Exhaust Ventilator

Picture 3

Water Damaged Ceiling Tile and Insulation, Basement Library

Picture 4

Water Damage, Basement Library, Note outside Light

Picture 5

Efflorescence and Water Damaged Ceiling Tiles, Basement Cafeteria

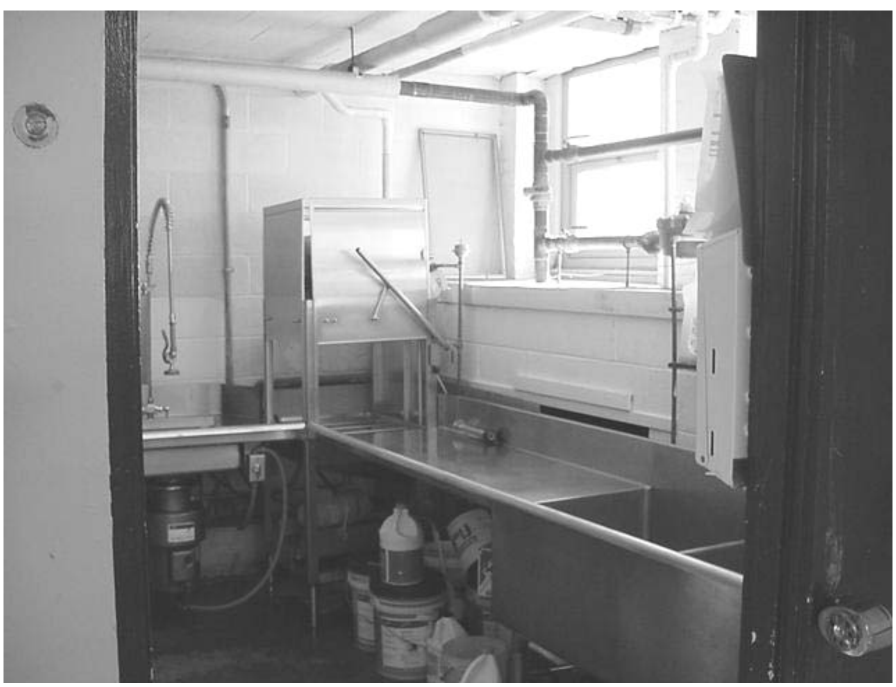
Picture 6

Roof Edge without Gutter

Picture 7

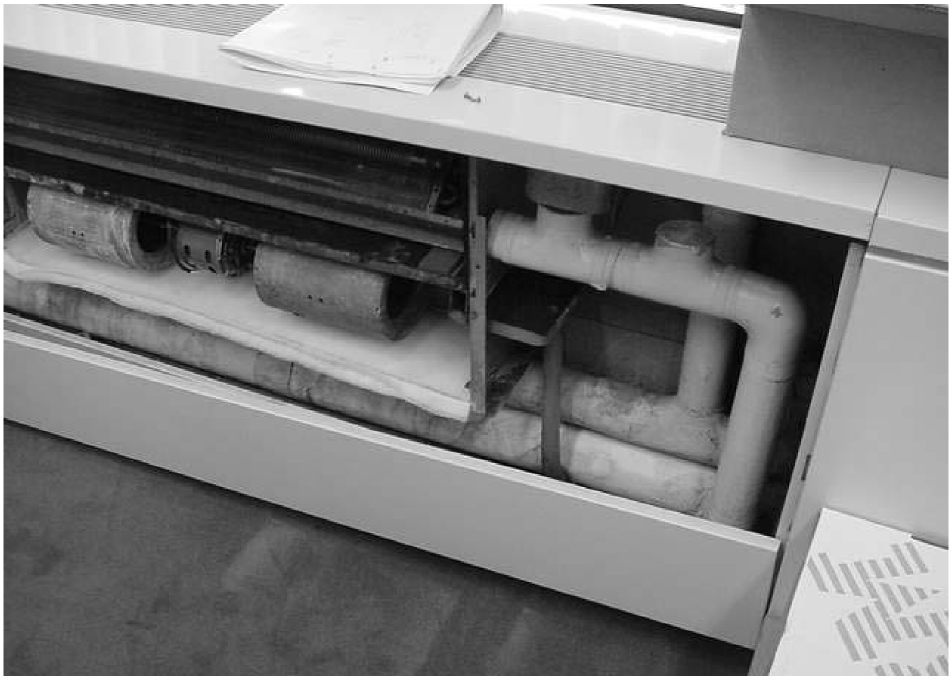
Wetting of Foundation and Windows by Splashing Rainwater

Picture 8



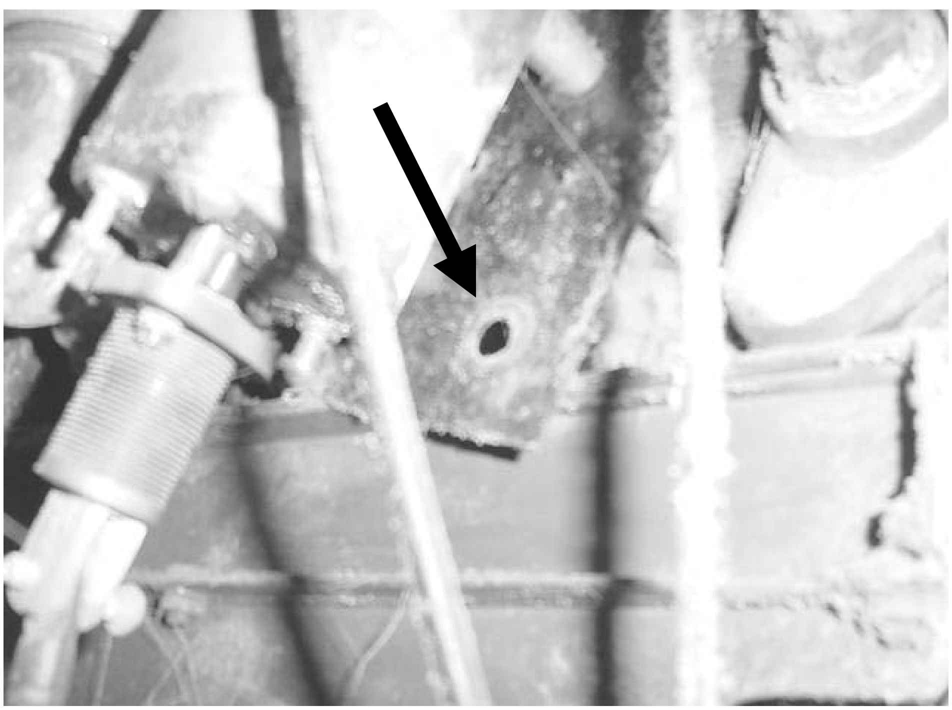
Automatic Dishwasher in Kitchen

Picture 9



Filter Media Cut To Fit Univent

Picture 10



Example of Hole in Univent Cabinet above Filters

Picture 11

“Glides” for Chair Legs that can be used as an Alternative to Tennis Balls

TABLE 1

Indoor Air Test Results

Helen A. Sauter Elementary School, Gardner, MA

February 17, 2006

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	Ultra-fine Particulate	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Outside (Background)	352	34	21	N.D.	N.D.	10					
Kerr	747	72	31	N.D.	N.D.	14	18	Y	Y	Y	Clutter Dry erase marker Door open
Heglin	892	72	33	N.D.	N.D.	18	23	Y	Y	Y	Clutter Dry erase marker Door open
Breakroom	929	73	35	N.D.	N.D.	21	4	Y	N	N	Door open
Riley	624	73	31	N.D.	N.D.	10	22	Y	Y	Y	Dry erase markers Window open Door open exhaust vent off
Whitelin	959	73	34	N.D.	N.D.	18	22	Y	N	N	Window-mounted air conditioner Clutter Door open window open
Aubuchon	821	72	31	N.D.	N.D.	27	21	Y	Y	Y	Window-mounted air conditioner Clutter

- **ppm = parts per million parts of air**
- **N.D. = non-detectable**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

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Helen A. Sauter Elementary School, Gardner, MA
February 17, 2006

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	Ultra-fine Particulate	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
											Univent blocked
205	578	72	30	N.D.	N.D.	8	1	Y	Y	Y	Door open
Nurse's office	692	73	32	N.D.	N.D.	15	3	Y	N	N	Door open
102	611	71	29	N.D.	N.D.	6	14	Y	Y	Y	Univent off Door open
Anderson	813	73	33	N.D.	N.D.	6	18	Y	Y	Y	Door open
Gallant	662	73	30	N.D.	N.D.	7	12	y	Y	Y	Door open
Office	441	68	44	N.D.	N.D.	37	3	Y	Y	N	
Photocopier room	488	72	40	N.D.	N.D.	40	0	Y	N	N	Door open
Gym	584	72	40	N.D.	N.D.	35	0	Y	Y	Y	Door
301	641	71	38	N.D.	N.D.	34	21	Y	Y	Y	Clutter Dry erase marker Door open

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									Supply	Exhaust	
Johnson	759	71	39	N.D.	N.D.	42					5 water damage ceiling tile Clutter Dry erase marker Door open
Nott	589	71	36	N.D.	N.D.	32	4	Y	Y	Y	1 water damage ceiling tile Door open
Guidance	357	70	28	N.D.	N.D.	1	1	Y	Y	N	Dry erase marker Door open
Speech	393	72	29	N.D.	N.D.	4	1	Y	N	Y	Exhaust vent off
Nott Anne	450	71	31	N.D.	N.D.	4	22	N	N	N	6 water damage wall tiles
Computer room	546	73	31	N.D.	N.D.	17	22	Y	Y	Y	Exhaust vent off 25 computer room Univent half covered by interior wall
Miller	544	73	29	N.D.	N.D.	10	22	Y	Y	Y	Clutter
Reading recovery	793	72	34	N.D.	N.D.	15	1	Y	Y	Y	Window-mounted air conditioner

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									Supply	Exhaust	
105	1017	74	35	N.D.	N.D.	17	0	Y	Y	Y	Univent off 1 water damaged ceiling tile Dry erase markers
Hallway outside 105	850	74	32	N.D.	N.D.	20	6	Y	N	N	
Art room	444	74	29	N.D.	N.D.	2	1	Y	Y	N	Dehumidifier Window-mounted air conditioner Tennis balls on chairs
Library	724	75	32	N.D.	N.D.	14	15	Y	Y	Y	Dehumidifier Window-mounted air conditioner Water damaged wall tiles

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